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THE WORK OF THE RESEARCH COUNCIL ON RIVETED AND BOLTED JOINTS

by W. C. Stewart

STRUCTURAL DIVISION

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EXPLANATORY STATEMENT

Practices in the design of riveted and bolted joints have developed largely from experience and have not always been supported by conclusive experimental data. With this fact in mind, twelve sponsoring organizations instituted the Research Council on Riveted and Bolted Structural Joints, in 1947.

Important among the projects of the Research Council is the study of high-strength bolts in structural joints. The high-strength bolt is a comparatively new type of structural fastener, and its use combines the field economies of bolts with strength greater than that of rivets.

At the Centennial Convention of the ASCE at Chicago, Ill., in 1952, a group of papers were presented describing research that had been done in the field of structural joints, with particular emphasis on study of the high-strength bolt.

These papers are currently being published as Proceedings-Separates and will be distributed over a period of several months beginning in May, 1954. Later, they will be gathered to form a single symposium in the Transactions of the ASCE. The six papers in this group are as follows:

"The Work of the Research Council on Riveted and Bolted Joints," by W. C. Stewart;

"Laboratory Tests of High-Tensile Bolted Structural Joints," by W. H. Munse, J. M. ASCE, D. T. Wright, and N. M. Newmark, M. ASCE;

"Comparative Behavior of Bolted and Riveted Joints," by Frank Baron, M. ASCE, and Edward W. Larson, Jr., J. M. ASCE;

"Slip Under Static Loads of Joints With High-Tensile Bolts," by R. A. Hechtman, A. M. ASCE, D. R. Young, and A. G. Chin and E. R. Savikko, Junior Members, ASCE;

"Fatigue in Riveted and Bolted Single-Lap Joints," by J. W. Carter and K. H. Lenzen, Associate Members, ASCE, and L. T. Wyly, M. ASCE;

"Structural Application of High-Strength Bolts," by T. R. Higgins and E. J. Ruble, Members, ASCE."

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THE WORK OF THE RESEARCH COUNCIL ON RIVETED AND BOLTED JOINTS

W. C. Stewart[1, 2]

The group of papers to be presented to you this afternoon describe research on the use of high tensile bolts as a structural fastener. This research has been carried out as one of the projects of the Research Council on Riveted and Bolted Structural Joints in a program to study the mechanical fastening of structures. So that you may better appreciate the presentation to be made, I would like to describe briefly what the Council is and how it came into being.

Undoubtedly the history of riveting goes back into antiquity as far as the use of ductile metals. The history of the formal study of riveting and bolting, however, is more recent. Mr. DeJong, in his bibliography, "Riveted Joints," published by the American Society of Mechanical Engineers, locates the first publication on the subject as about the middle of the 19th Century. It is quite fitting, therefore, that reporting of a major advance in the science of structural fastening should occur a century later during this Centennial of Engineering.

The Research Council on Riveted and Bolted Structural Joints arose out of discussions between Professor W. M. Wilson of the University of Illinois, the late Professor G. A. Maney of Northwestern University, Mr. Herman H. Lind, President of the Industrial Fasteners Institute, and the late Professor Charles A. Ellis of Purdue University who was at the time chairman of the Research Committee of the American Society of Civil Engineers.

The Council was organized January 15, 1947, and consists of representatives of twelve sponsor organizations together with a number of additional individuals who have been invited to participate because of their eminent qualifications to assist the Council's work. The organizations sponsoring the Council are:

American Institute of Steel Construction
American Iron and Steel Institute
American Society of Civil Engineers
Association of American Railroads
The Engineering Foundation
State of Illinois, Division of Highways
Industrial Fasteners Institute
U. S. Department of Commerce, Bureau of Public Roads
University of Illinois
Northwestern University
Purdue University
University of Washington

In forming the Council, it was recognized that many existing practices in the design of riveted and bolted connections, while serving well for many

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years, were developed empirically through experience. Some of the practices, and the joint capacities predicated on them are not supported by conclusive scientific data. The Council was organized to carry on such investigations as may be necessary to determine the suitability and capacity of various types of joints used in fabricated structural frames. It has been expected that the Council's work would result in the promulgation of more economical and more efficient practices.

In order to acquaint you with the extent of the Council's activities, I would like to state briefly the objectives of the various projects under way.

Project 1, under the chairmanship of Mr. Jonathan Jones of the Bethlehem Steel Company, is concerned with the effect of bearing pressure on the strength of riveted joints. It is common knowledge that additional riveting is required by current specifications solely because of limitations of bearing pressure. There appears to be little basis in fact for this restriction and if a more liberal, but safe, value can be found, it will result in economic savings.

Project 2, under the chairmanship of Professor N. M. Newmark of the University of Illinois, is studying the static strength of structural joints having various rivet patterns. The objective is to determine improved methods of reliably predicting the static efficiency of joints.

Project 3, under the chairmanship of Mr. T. R. Higgins of the American Institute of Steel Construction, is investigating the strength of rivets in combined shear and tension. Most specifications discourage the use of rivets in tension though it is obvious that many rivets are subjected to tensile forces. The purpose of this project is to determine safe rules for design, recognizing that rivets may be subjected to tension as well as shear forces.

Project 4, of which I am chairman, has as its objective the study of structural joints fastened with bolts. The papers to be presented this afternoon will deal with the work of this project.

Project 5, under the chairmanship of Mr. E. J. Ruble of the Association of American Railroads, is concerned with the effect of grip length of fasteners on the fatigue strength of structural joints. Certain fasteners may produce better results in long grips while others may give better results in short grips. It is desirable to know just what these relations are.

Project 6, under the chairmanship of Mr. C. Neufeld of the Canadian Pacific Railway, is studying the comparative fatigue strength of carbon, silicon, and low-alloy structural steels and of joints made in these materials. Silicon and low-alloy steels have static strength advantages over carbon steel. The objective here is to find out if they have comparable advantages in fatigue so that these materials can be properly utilized in structures subjected to this type of loading.

Project 7, under the chairmanship of Mr. R. B. Murphy of the State of Illinois, Division of Highways, is studying the effect of rivet pattern on the fatigue strength of connections with the objective of determining patterns of superior endurance. This project is similar to Project 2 in that it studies rivet pattern but the criterion is fatigue strength rather than static strength.

Project 8, under the chairmanship of Professor W. H. Munse of the University of Illinois, is a new project just recently authorized. Field tests on railway girders show that only 7 per cent of the trains passing over these bridges produce stresses near the maximum. About 20 per cent produce stresses from 80 to 90 per cent of the maximum. The remainder produce stresses less than 80 per cent of the maximum and as low as 40 to 50 per cent. Current fatigue tests in the laboratory are run with a constant stress cycle which is unrealistic when correlated with railway loading. The object

of Project 8, then, is to determine the comparative fatigue strengths under varying cycles of loading which approximate actual service.

The Council has been in operation nearly six years. Certain of these projects have been completed, or, at least, phases have been finished. A number of papers are now in preparation and will be made public in due course. The series of papers to be submitted this afternoon represent the first formal presentation of the Council's work. The research to be presented is limited to the investigation of connections using high tensile bolts. It is felt that this information is most immediately required by the engineering profession.

Possibly no structural research in recent years has brought about so immediate and so extensive a modification of structural practice as the study of the high tensile structural bolt. For this reason, I think it will be of interest to rapidly trace the historical development of the high tensile structural bolt. The type of bolt is not new, but its extensive application to structural joints is of recent origin. The bolt is an accurately controlled, quenched and drawn, medium carbon steel bolt. This type of bolt first came into general use shortly after the First World War as an aid in building better automobiles. The idea, in applying this bolt to structures, is simply to use a high tensile bolt torqued to a very high tension and supported by hardened washers under the bolt head and the nut. This idea, however, and its effects, did not emerge at one time, but only through a process of development and contributions of many engineers.

Possibly the germ of this idea lay in the practice of certain fabricators, a good many years ago, of using similar high-strength bolts as "fitting-up" bolts. This provided sufficient clamping power to pull up heavy plates preparatory to riveting.

The first laboratory tests on high-strength bolts that I am aware of in this country were performed by Professor Wilbur Wilson at the University of Illinois and published in the University's Bulletin 302 in 1938. Wilson concluded that "The fatigue strength of high-strength bolts, appreciably smaller than the holes in the plates, was as great as that of well-driven rivets if the nuts were screwed up to give a high tension in the bolts." The joints tested, however, were designed for failure in the bolts rather than the plates and the bolt tensions were low as we know them now. The tests did establish, however, that the bolts themselves would not fail in fatigue if suitably tightened.

The next step came in 1945 when Professor G. A. Maney of Northwestern University, under the sponsorship of the Industrial Fasteners Institute, prepared drawings for joints of more nearly balanced design. Difficulties were encountered in testing these joints in reverse loading because the bolt tension was lost due to the bolt head and nut indenting the structural plate, thereby losing grip. It had not yet been realized that hardened washers were necessary under the bolt head and nut to support the high bolt tension. Mr. Kenneth H. Lenzen, then at Northwestern University, was conducting these tests. He experimented with various washers—common soft washers, cyanide hardened washers, deeply carburized washers, quenched and drawn medium carbon steel washers, and in the end, on October 23, 1947, obtained the first successful test of a balanced joint designed pretty much as we know it today.

In the meantime the Research Council was formed, and, under its sponsorship, during the spring and summer of 1947, Professor Wilson at the University of Illinois completed tests of a series of bolted joints designed for failure of the bolts but with bolt tensions much higher than he had previously used. Here, again, it was determined that the bolt itself was safe in fatigue even when tightened to very high levels. Since that time, the University of Illinois and later, the University of Washington, have continuously explored numerous

ramifications of the bolted joint problem. Also, additional information has been obtained in connection with another project by Professor Frank Baron of Northwestern University.

Concurrently with these developments, Professors L. T. Wyly and J. W. Carter at Purdue University, under the sponsorship of the American Railway Engineering Association, were studying the problem of fatigue failures of floor beam hangers of railroad bridges. In reviewing these fatigue failures in the hangers, Professor Wyly advanced the hypothesis that the failures were due primarily to high stresses and strains induced by rivet bearing. The high clamping bolt was proposed as a remedy to minimize the effect of this bearing. This explanation with supporting evidence was presented to AREA Committee 15, Iron and Steel Structures, at Purdue on October 19, 1948. This thesis was subsequently verified by Wyly and Carter by fatigue tests on single lap joints connected by rivets, bolts in bearing without clamping, and by high clamping bolts. Detailed studies of stress and strain in the vicinity of rivet and bolt holes, by J. W. Carter, were correlated with the fatigue tests.

During the course of these events, the Association of American Railroads became interested in the possibilities of these bolts in maintenance of bridges and embarked on a program of field installations. The first of these installations was on March 19, 1948 in an ore bridge of the Pennsylvania Dock Company at Ashtabula, Ohio.

Realizing the importance of these bolts, the American Society for Testing Materials appointed a Committee to prepare specifications to control the quality of these bolts. These tentative specifications were approved in 1949 and revised in 1951 under the ASTM designation A-325.

The Research Council, as a result of its research activities and in order to provide industry with suitable control of the assembly of high tensile bolts, prepared "Specifications for Assembly of Structural Joints Using High Tensile Steel Bolts" which were approved by the Council in January, 1951.

The high tensile bolt, in the design required for structural use, was not generally available at the beginning of these investigations, though slightly different products of the same physical properties were widely used. The American Standards Association, responsible for the standardization of bolt design, has considered the problem, not only from the viewpoint of American standards, but in cooperation with standardizing bodies of Great Britain and Canada. As a result, the American Standards Association in March of this year, approved a new standard which will improve the availability of the high tensile bolt for structural use.

So you see the development of the idea of the high tensile structural bolt has progressed step by step with participation and contributions of many individuals and organizations. The rapid progress made and the ready application of the idea to practice is truly a remarkable example of cooperative endeavor to provide the profession with a new tool. We hope that the papers to be submitted this afternoon will assist you in understanding and properly using the high tensile structural bolt.

June 26, 1952

PROCEEDINGS-SEPARATES

The technical papers published in the past twelve months are presented below. Technical-division sponsorship is indicated by an abbreviation at the end of each Separate Number, the symbols referring to: Air Transport (AT), City Planning (CP), Construction (CO), Engineering Mechanics (EM), Highway (HW), Hydraulics (HY), Irrigation and Drainage (IR), Power (PO), Sanitary Engineering (SA), Soil Mechanics and Foundations (SM), Structural (ST), Surveying and Mapping (SU), and Waterways (WW) divisions. For titles and order coupons, refer to the appropriate issue of "Civil Engineering" or write for a cumulative price list.

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a. Beginning with "Proceedings-Separate No. 200," published in July, 1953, the papers were printed by the photo-offset method.
b. Presented at the Miami Beach (Fla.) Convention of the Society in June, 1953.
c. Presented at the New York (N.Y.) Convention of the Society in October, 1953.
d. Beginning with "Proceedings-Separate No. 290," published in October, 1953, an automatic distribution of papers was inaugurated, as outlined in "Civil Engineering," June, 1953, page 66.
e. Discussion of several papers, grouped by divisions.
f. Presented at the Atlanta (Ga.) Convention of the Society in February, 1954.

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